# Overview of Herbage Assessed Remotely to Predict Environmental Risk (HARPER) Mulch Classification and Assessment Process

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There is an ongoing need for rangeland managers to assess mulch retention levels on California Annual Grasslands each fall, prior to the rainy winter season. This is not a recently identified need.

## Why Monitor Mulch in the fall?

Extensive research has shown that rangelands require an adequate level of mulch to maintain a healthy productive ecosystem. Inadequate mulch results in rangeland deterioration, excess levels of mulch can lead to monocultures with reduced biodiversity and forage production. The amount of mulch to retain varies by ecotype and management objectives. Desired mulch level is typically referred to as "moderate".

## Visual based survey techniques have been recommended for monitoring mulch retention levels for many years.

The following references are some of the recommendations for using a visual based survey to determine how well a pasture/management unit meets the goal of moderate mulch retention.

1942- Hormay suggested that ranchers should measure and evaluate "Forage left on the ground from the previous year's growth." This early research note included a set of six example photographs to assist in determining moderate use. Moderate use was to retain 40-50% of annual production.

1951 – Bentley and Talbots publication suggested ranchers graze at a moderate utilization level. The Moderate level was described as a goal that retained 40-60% of annual production.

1956 – Heady's publication suggested range managers should manage for mulch and defined it as "The portion of herbage crop that remains on grasslands is mulch".

1980 – Bartolome et al. measured "Mulch or plant residue."

1982 – Clawson- Noted that the recommended level of grazing was moderate. The publication also noted that "Moderate grazing also provides more residual dry matter than listed in the minimum guidelines described…". A photo guide was included to assist in evaluation of mulch levels.

1996 – Interagency Technical Publication BLM-1730 "Utilization Studies and residual measurements" This publication includes 6 different survey methods based on visual survey techniques.

**Note:** *All of these references rely on well-trained and experienced Range Examiners/personnel to produce a useful survey.*

## Why is mulch monitoring not consistently conducted using a visual based survey?

There are several reasons that visual based monitoring may not be conducted.

**--Concern for inherent bias when evaluating complex landscapes.** Bias can be a problem with untrained or minimally trained personnel. Clipping and weighing numerous sample plots is sometimes considered a solution to bias. Unfortunately trying to eliminate bias by collecting precise data from numerous small plots is time consuming and still has a high error rate on complex rangelands.

**--Lack of trained and experienced personnel.** The lack of trained personnel to conduct visual based surveys may result in using survey strategies that can be implemented with minimal training. A simple clip and weigh monitoring program results in numerous plots used to create averages that have high error rates.

**--Trained and experienced personnel are available, but the time allocated is not adequate to survey all portions of a property.** Time constraints may limit the time trained and experienced personnel have to survey a property, especially large properties with poor access. The results are that key portions of the property may not be surveyed.

## Can satellite imagery increase the efficiency and effectiveness of monitoring mulch retention on California Annual Grassland sites?

The question can be rephrased as "Since rangeland managers can be trained to classify Grasslands as Low, Moderate and High mulch using the 3 light bands of Blue, Green and Red provided by the human eyeball, can computers be trained to classify Grasslands using the 11 light bands provided by high resolution satellite imagery?"

Satellite imagery can:

-Reduce range examiner bias concerns.

-Provide an assessment that shows the complexity of rangeland ecosystems and identify areas of High, Moderate, and Low mulch levels plus burned and non-forage areas.

## Wildland Solutions Development of HARPER process.

Criteria for developing the HARPER process included utilizing no-cost imagery, desktop computers and readily available low or no-cost analysis programs that do not require formal GIS training.

In 1998-1999 Wildland Solutions initially looked at the potential for use of satellite imagery to assess mulch retention. The early assessment was promising; however, the imagery was costly, needed to be georeferenced, difficult to analyze on desktop computers and provided results typically one year after the imagery was taken.

2008- LANDSAT satellite imagery is made available to the general public at no cost.

2014 – With no cost imagery available, Wildland Solutions began a new analysis to evaluate satellite imagery as a tool to classify mulch retention levels. Landsat satellite imagery and ARCMAP GIS were selected for use.

2015– 2017 Field testing of an initial HARPER process was conducted on three properties.

1. 1,500-acre private property with 5 pastures near Gustine.
2. 34,000-acre BLM area with 23 pastures at Carrizo Plains
3. 37,878-acre TNC preserve with 17 pastures in Northern California.

2018- Results from 2015-2017 HARPER classifications of mulch were strongly correlated with ground surveys that were conducted on the properties. An overview of the HARPER process was presented at the technology session of the Society for Range Management meeting in Sparks, Nevada (January 2018). Session moderator commented that he thought it was the most practical presentation made.

2018- 2019- A total of 10-12 properties were assessed each year using the HARPER process and LANDSAT imagery. Mulch retention maps were created for TNC, USFWS, private and SCVOSA. Results for SCVOSA properties showed correlations of 86-91% between HARPER assessment and field survey estimates.

2020-2021 – Wildland Solutions changed from using USGS LANDSAT imagery and ARCMAP for analysis of imagery to using high resolution European Union Sentinel imagery and ARCGIS PRO for analysis of imagery. Advantages were Sentinel imagery provides 9 times the number of pixels or almost 40 pixels per acre instead of 4 pixels provided by LANDSAT. Sentinel also provides new imagery every 5 days compared to 16 days for LANDSAT. The additional imagery improves the ability to obtain high quality imagery free from clouds and smoke that can occur during the desired timeframe just prior to fall rains. ARCGIS PRO is also more advanced than ARCMAP and ESRI intends to discontinue support for ARCMAP within the next couple of years. A total of 7-8 properties were assessed and mulch retention maps created each year using the HARPER process in 2020-2021.

2022 – A total of 8 properties, plus the Kern Refuge, were assessed with mulch retention maps created. The USFWS Kern refuge biologist used a draft HARPER process guide to successfully develop mulch retention maps for the Pixley refuge after she assisted with the process in 2020-2021.

## Overview of HARPER Process 2014-2023.

The HARPER concept for monitoring mulch levels is similar to visual monitoring techniques used by trained range examiners/personnel in many regards.

**-----Establish the desired mulch level**. The desired goal needs to be a range or class of mulch/RDM and variously described as Proper Use, Moderate use, Residual forage, Residue, or Residual Dry Matter (RDM) class. Example would be "Moderate mulch retention as 800-1,600 lbs./acre" This step needs to be done for both the traditional range examiner survey and the HARPER assessment process.

**-----Training is needed to identify what the desired level of Moderate mulch retention "800-1,600 lbs./acre" looks like.**

To train any range examiner a series of plots that represent high, moderate, and low mulch levels need to be first located and identified. Then plots are clipped and weighed to determine what the desired mulch level "looks like", sometimes referring to a photo guide if available.

The HARPER process also needs to be trained to identify what the desired level of mulch "looks like". To train the computer a series of plots representing high, moderate, and low mulch levels also needs to be located then clipped and weighed to verify which classes of mulch they represent. A program, Training Samples Manager, which is built into ARCGIS is then used to develop a "signature", for each mulch class, using the example plots identified in the field survey. The signature developed for each mulch class is much like an example picture of mulch retention selected for a photo-guide.

**-----Classify the grassland sites being evaluated.**

The traditional range examiner each year must clip and weigh enough plots to recalibrate their eyes and estimates. Accurate estimates can then be made without clipping and weighing every plot. The range examiner uses the 3 light bands Blue, Green and Red, located in their eye, to mentally compare what they see in each survey plot, with the training plots they previously clipped and weighed. Obviously, areas near roads and good access tend to receive more attention than areas with poor access.

The HARPER assessment is conducted by using the signatures developed by the computer program for each mulch class. The computer first looks at the signature of each pixel (40 per acre) within the pasture, compares the signature to the sample signatures developed for each of the mulch classes, then assigns the pixel a value that is the best fit to the sample signatures. All parts of the management unit are surveyed in the same manner.

**------Create a map for visual display of mulch levels**.

The range examiner may or may not create a map that shows mulch levels, burned and non-forage areas. The accuracy and time needed to create a map depends on the skill of the range examiner, and the complexity of vegetation types within the property.

The HARPER process automatically provides a map ready to be printed as part of the classification process. Classified mulch levels, burned, and non-forage areas for the entire project area are shown. Just add a legend. The mulch class percentages within each pasture can be easily calculated using built-in GIS programs.

## Findings and conclusions based on results from the 41 HARPER assessments conducted by Wildland Solutions on 17 different properties from 2014-2022.

## Key findings:

1. An important benefit of the HARPER process is the ability to create maps that reflect the complex variation of a landscape, which plot-based data with averages cannot do.
2. The HARPER process automatically creates a map that shows the location of Non-forage, Burned, High mulch, Moderate mulch, and Low mulch within each pasture/management unit.
3. Aspect has an influence on mulch retention unrelated to livestock grazing. The HARPER process will classify low producing south slopes as low mulch and more productive north slopes as moderate or high on a fine scale. Typical zone maps can only classify mulch on a coarse scale.
4. Burned areas, reservoirs and ponds are correctly classified with near 100% accuracy.
5. Non-forage areas including alkali flats, oak woodland, and mixed chaparral can be identified and classified (estimated 90-95% accuracy) by the HARPER process. These areas can then be shown as non-forage areas, or "Other" and excluded from analysis.
6. The HARPER process does not assess forage directly. It measures residual herbage, mulch, or Residual Dry Matter (RDM), which includes old mulch, leaves and non-palatable forbs. Estimates of residual forage can be calculated using the data generated by the HARPER process.
7. California Annual Grassland sites with annual bromes and rye grass that produce 1,800-3,000 lbs./acre of herbage annually are monitored effectively using the HARPER process.
8. Grasslands with mulch levels between no mulch and mulch levels up to about 1,800-2,000 lbs/acre can be effectively classified into 2-3 classes using the HARPER process.
9. Sites with more than 1,800-2,000 lbs./acre of mulch have a similar visual signature as sites with 3,000 lbs/acre or 4,000+ lbs/acre of mulch. All sites above 1,800-2,000 lbs/acre need to be merged into a single "High mulch" class.
10. Sites that are dominated by tall Oat grass that retain 3,000-6,000 lbs./acre of herbage may provide inconsistent results by being mis-classified as low mulch, when the oatgrass areas with high mulch have been trampled by livestock or flattened by rain.
11. Rocky serpentine soil sites tend to have adequate mulch to meet soil protection and ecological needs. Serpentine soil sites are difficult to classify with both traditional clipping and weighing techniques and the HARPER process. The vegetation that is present has a high portion of forbs, which may or may not be included as forage/RDM. Forbs tend to produce HARPER signatures that indicate more mulch than is actually present.
12. Some low forage sites with late season forbs such as tar plant or star thistle will be classified by the HARPER process as having high mulch, which is correct when considering herbage/mulch retention for soil protection. The site has a noxious weed and low forage production problem but likely has adequate or high herbage/mulch retention that meets soil protection goals.
13. Some error is unavoidable when monitoring. Error rate of HARPER classified imagery has not been measured statistically. However, the process consistently provides valuable information related to mulch retention levels and non-forage areas that plot based averages or zone maps cannot provide. The error rate for HARPER maps will be reduced as the process is refined.

Figure 2: Shows the classified mulch retention levels for the upland Management Units (MU) of the Pixley refuge. The location of Low, Optimum, Marginal and Unsuitable mulch areas within each MU is apparent. The speckled look of the map reflects the inherent patchy areas of mulch retention due to irregular grazing, access to water and soil variability that occurs within each management unit.

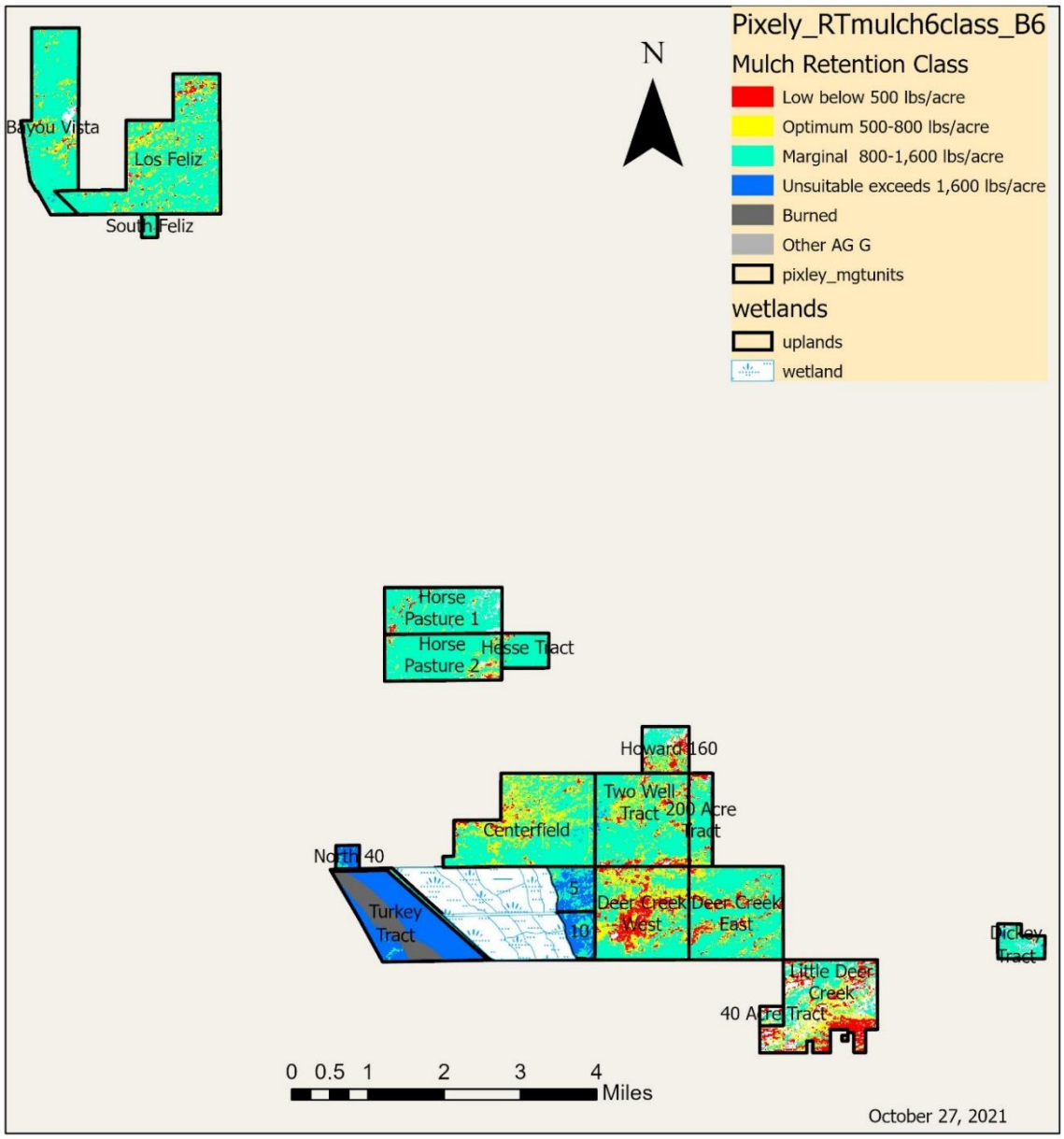



Fig: 2 Pixley Refuge 2021 Classified Mulch Retention Map

**Optimum in this survey is 500-800 lbs/acre designation for Blunt nosed leopard lizard habitat.**

**The low areas are mostly associated with watering sites.**

**Figure 2B** shows the 2021 mulch retention levels for the Rancho Canada del Oro OSP as classified by the HARPER process. The location of moderate and high areas of mulch within each MU is apparent. Most of the small southern MU, GA-5, was correctly classified as low mulch retention. The majority of RCDO OSP forage areas in GA-3 and GA-4 were classified as high or moderate mulch. Some small areas of low mulch associated with south slopes and water sources were identified in the two northern MUs, GA-1 and GA-2.

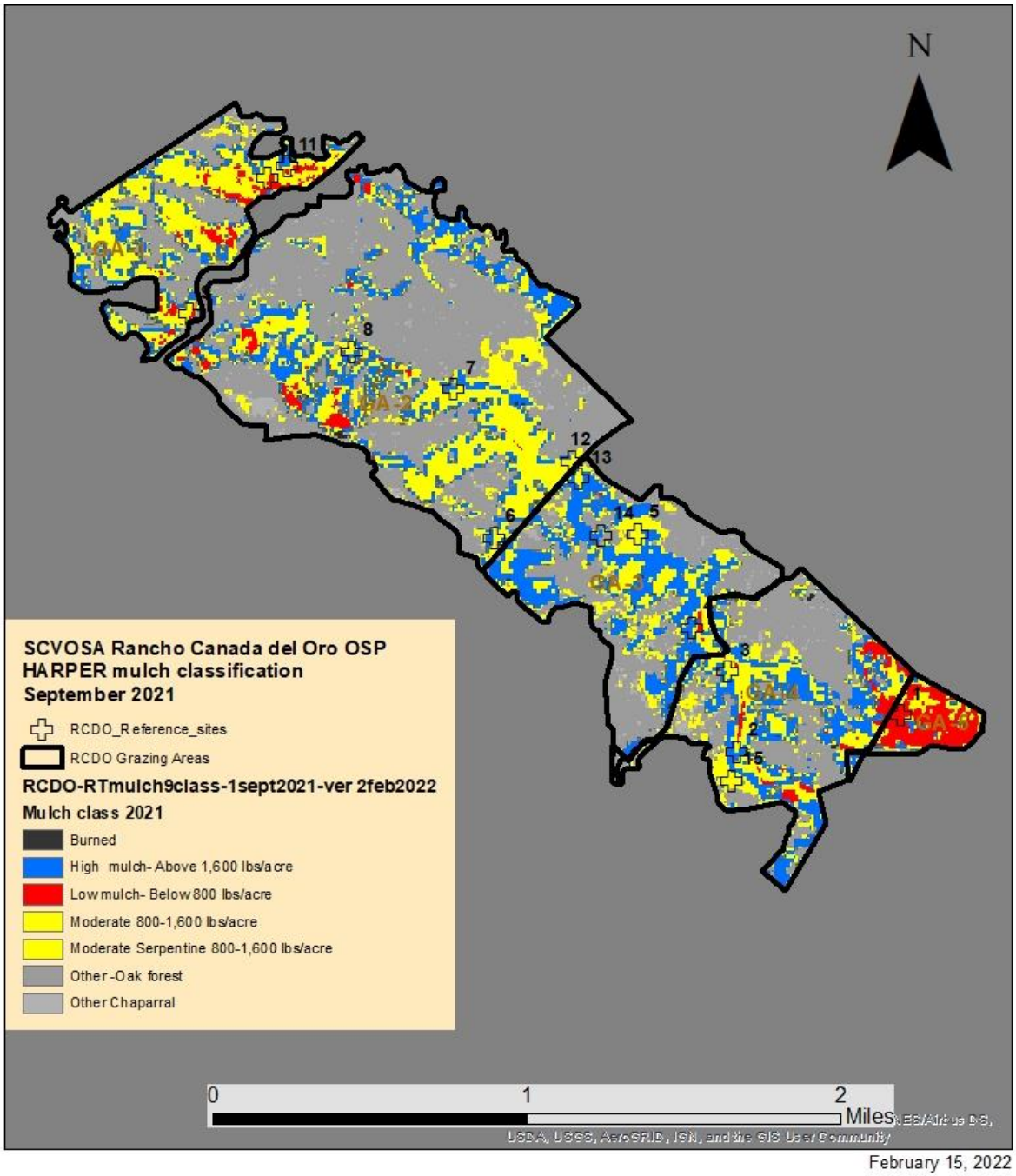
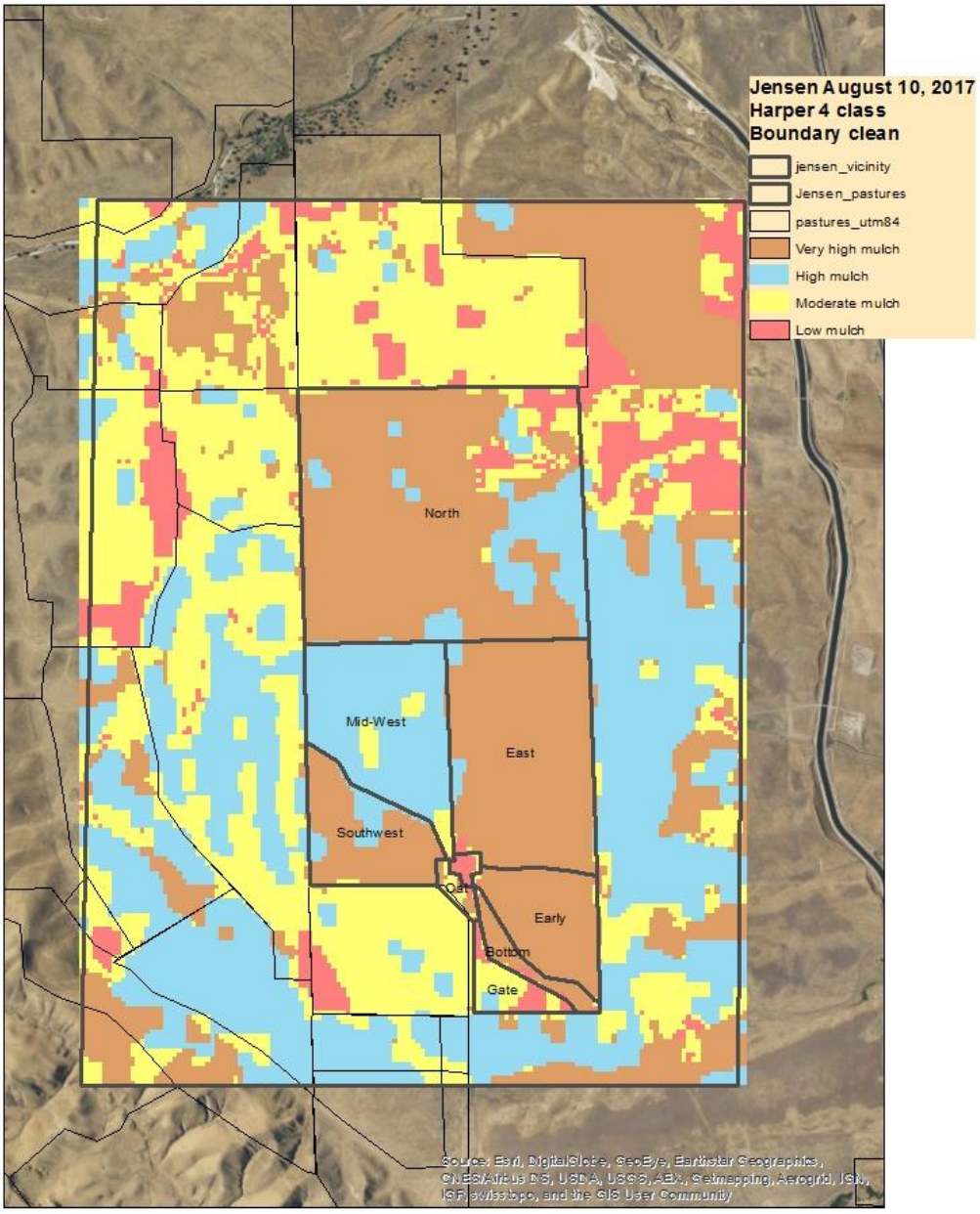



**Figure 2B: Mulch retention classification**
**Rancho Canada del Oro 2021**




**Fence line contrasts are apparent between management units grazed at different intensities.**

**The low mulch areas are all associated with water sources or low production soil sites.**